Institution: University of Oxford

Unit of Assessment: Materials UOA13

a. Overview

The UoA comprises the Department of Materials, which is one of the ten departments in the Mathematical, Physical and Life Sciences (MPLS) Division, one of four academic Divisions in the University of Oxford. Our submission involves 35 staff from the Department of Materials which is also home to 64 post-doctoral research associates and >160 PhD students. In 2012/13, the department had an overall turnover of £8.3M with an additional research-grant expenditure of £6.3M, producing 1,185 publications in the REF period (WoS October 28th 2013) that were cited 12,600 times.

Our objectives are to train world class materials scientists and to conduct internationally leading, strategic research into the manufacture, structure, properties and applications of engineering materials. Achievements during the assessment period include:

- Appointing 11 new faculty members to expand substantially the research activity in strategic target areas of materials modelling, energy materials, manufacturing and carbon nanomaterials, with an overall increase in permanent faculty from 21 to 25.
- Successfully applying for an Athena Swan silver award, in the process fully reviewing and improving mechanisms for supporting our research staff.
- Growing PhD student numbers by over 40% since RAE2008 to the highest in our history. Our ratio of students in years 1-4 to submitted staff has increased from 2.4 in 2008 to 4.1 in 2013.
- Increasing external grant awards from an average of £7.2M in 2008-2011 to £13.9M in 2012/13.
- Investing more than £12M in new research facilities and moving into an expanded Materials Modelling Laboratory.
- Partnering in 3 successful CDT bids announced in November 2013, involving 6 staff members.

b. Research Strategy

Vision and strategic aims

Our vision is to tackle difficult research problems at the forefront of the discipline and to address intellectual challenges relevant to wider society. Our research strategy is to maintain world-class core expertise in characterisation, processing, properties, and theory and modelling, and to build this expertise into flexible teams of researchers to address complex, multi-faceted problems that cross competence boundaries and conventional disciplines. We have strategically expanded our research capability in nuclear materials, devices for quantum information and manufacturing, while other research areas have been reduced in prominence e.g. corrosion. Progress against strategic research aims (1-4) defined in RAE2008 are described below, along with other key developments in our research strategy and capability.

1. *To expand new research programmes in photovoltaics and materials for fission and fusion, as well as to contribute to major new university initiatives on NanoScience and Catalysis*.

- We have significantly expanded work in energy materials, especially those for nuclear power generation, supported by a £6M EPSRC Programme Grant (**Roberts** *et al*), 9 other RCUK grants and a large number of industrial contracts. More than 65 full time researchers now work in nuclear materials (3 in 2007). Strategic appointments to build capability in nuclear materials have been made both at professorial level (**Marrow** – new externally funded statutory chair) and younger academic staff (**Lozano-Perez, Armstrong**). This team now publishes >100 papers each year in major journals.
- We take the Oxford-lead in the Bristol/Oxford Nuclear Research Centre that was launched in 2011, coordinating research between the two universities that has already secured three large joint projects with a value >£3M.
- We took the lead in 2012 (with Imperial College, Manchester, NNL and the Culham Center for Fusion Energy - CCFE) in the design of the £15M National Nuclear Users Facility announced in the Beddington Nuclear Review (2013), and now oversee the installation of equipment at CCFE.
- We have expanded research in nanomaterial synthesis and manufacturing, including topical materials such as graphene, by three appointments (**Grobert, Warner, Bhaskaran**), leading to, for example, 4 papers in the *Nature* family on defects in 2D crystals.

- In 2009, we reaffirmed our commitment to materials for quantum information processing with the appointment of **Benjamin**. A £1.2M EPSRC Platform Grant in 2012 (**Briggs**), a £1.5M EPSRC Manufacturing Fellowship in 2013 (**Porfyrakis**) and several charitable donations now support a large and productive research effort that attracts excellent younger fellowship holders (**Laird**, **Simmons**). Research highlights include world leading values for the lifetime of entangled states and the most reliable schemes for quantum processing (reported in *Science* and *Nature*).
- We have developed closer contacts with Physics on photovoltaics and with Chemistry on catalysis that have resulted in new joint grants on semiconductor-sensitised solar cells and new papers in *Nature Nanotechnology* on the catalytic activity of core-shell nanoparticles.

2. *To establish nano-metrology facilities to underpin new world-leading research projects in nano-characterisation and nano-devices*.

- With Physics and £880k support from the university, we have established a new jointly managed nano-manufacturing facility, including electron beam lithography, which underpins projects in C-nanotube and graphene FETs for spintronics and flexible transparent electronics.

3. *To reinforce our modelling research through the filling of newly created posts in Materials Modelling; and to fill the Isaac Wolfson Chair with a scientist of international renown.*

- Peter **Bruce** FRS will take up the Isaac Wolfson Chair in January 2014, substantially expanding our activities in energy materials, especially in battery technologies.
- Modelling activity has been expanded both by staff appointments (**Yates, Giustino**) and a new 300 m^2 Materials Modelling Laboratory, covering research in a much wider range of topics than in 2008 with 6 times the research income, including from the 1bn EU FET Graphene Flagship project. As part of expanding our nuclear capability, **Fitzgerald** was appointed to a new post in dislocation modelling (2013). This expansion has been supported by new computing facilities in the department as well as a 5X increase in time allocated on the Oxford Supercomputer.
- Research highlights include the first fully consistent theoretical analysis of the catastrophic loss of strength in nuclear ferritic alloys at high temperatures, and the prediction of efficient new sensitisers for 3rd generation solar cells that have subsequently been confirmed experimentally.

4. *To increase long-term research activity with UK and international companies, ensuring that the output will have a meaningful impact on industrial practice.*

- Most of our research involves linkages to end-users, and some recent examples of research activity strongly linked to industry include those in: energy storage (**Grant** with Nexeon, Oxis Energy), metamaterials (**Grant, Grovenor** with DSTL, Cobham, BAE Systems) H embrittlement in engineering materials (**Moody** with SKF, ThyssenKrupp and Sheffield Forgemasters) and materials for extreme environments (**Reed** with Rolls-Royce and Siemens and **Grant** with MHI)
- We have forged new industrial research partnerships with Baosteel in China, KETEP in Korea (**Grant**), and with Samsung (**Smith**).

Planning research strategy

We set ambitious targets for the generation of external research funding, and aim for a mixed portfolio of research council, EU, charity and industrial grants. Planning is managed by the Research Opportunities Group (ROG), which takes a long-term view of our overall research portfolio, facilities and expertise, and explores new opportunities and funding sources. ROG advises the Head of Department (HoD) (elected on a 5 year term) who tensions this advice with the MPLS division and university strategic plans. Our policy has been to place greater emphasis on longer/larger applications, which – for example - has led to leadership or participation in ten 5-year multi-£M RCUK projects (QUEST, MFFP, LiME, HEMS, SuperGen energy storage, Grid Storage Grand Challenge, etc). In 2011 we established regular thematic meetings of academic and research staff to facilitate planning for and preparing ambitious larger applications in *device materials, materials processing, materials synthesis and nuclear materials*, each reflecting about 25% of the research activity in the department. Other outcomes of these planning activities have been:

- A £2.1M EPSRC grant in 2013 for a South of England analytical transmission electron microscope (**Grovenor** *et al* with Bristol and Southampton).

- New long-term research partnerships with CCFE and Fermilab (**Roberts**), Westinghouse (**Grovenor**) and Areva (**Lozano-Perez**)
- Successful applications for £4.9M of new equipment under EPSRC's Eight Key Technologies scheme (Advanced Materials, Grid Scale Storage) in 2013 (**Reed, Grant, Grovenor**)

We have two further strategies to develop research activity. Firstly, we established the Oxford Materials Characterisation Service (OMCS) in 2002 to carry out service-based research for industry. OMCS has grown from 4 FTEs in RAE2008 to 8 FTEs, during which period we have evolved OMCS into a key instrument for broadening our industrial research portfolio. Other than its high-level service work, OMCS is providing a gateway to turn industrial customers (currently more than 400) into research partners. During the period of assessment, initial service-based interactions that developed into new industrially-funded research projects include those with Ketonex, Glide Pharma, CEH, HPA, GE Aviation, CRDM and NNL. Secondly, we employ the team of the Transport node of the Materials Knowledge Transfer Network (KTN), which comprises 2-3FTE technology translators, using funding from the Technology Strategy Board. The focus of this team has been to secure research and development funds for UK companies and universities in the transport sector. Since 2008, the KTN team have initiated and managed 38 projects with a total value of >£42m, involving >100 industrial partners. Although a pan-UK activity, many industrial research opportunities have arisen for members of the department, and approximately 15% of the projects have involved the department.

c. People

i. Staffing strategy and staff development

Our overall staffing strategy is to recruit world-class materials science researchers through open competition, and to provide them with excellent facilities, high quality research students and a research environment that facilitates the highest levels of achievement. Academic appointments are encouraged and supported to pursue individual research agendas, within an environment that provides myriad opportunities for collaboration and inspiration from other scientists across the materials discipline, the MPLS division and the wider university. The college system provides a potent mechanism by which staff interact with researchers from other disciplines.

Equality and diversity: We were awarded a Silver Athena SWAN Award in 2012. The application process was an excellent opportunity to reflect on existing practices to encourage diversity and support equality, and how to improve them. The award also came with detailed feedback that we have incorporated into an action plan which we are currently addressing.

Academic staff: On 31/10/13, our academic staff consisted of 13 Professors, 8 University Lecturers, 2 permanent Research Lecturers, 2 Departmental Lecturers, 13 Senior Research Fellows funded by external fellowships and 64 postdoctoral researchers, supported by 5 senior administration staff and 37 technical/secretarial staff. The primary responsibility for identifying fields of research for upcoming academic appointments rests with the Departmental Committee with the HoD as Chair, advised by ROG and staff meetings that consider new scientific opportunities for the subject, and growing (and declining) areas. We are committed to hiring the best academic staff from anywhere in the world, and we use high visibility advertising (e.g. Nature journals) and an active search strategy to capture the attention of the widest field of applicants. Recent international appointments are **Giustino** (Berkeley) and **Moody** (Sydney).

Since 2008, 7 academic staff have left: Marzari to ETH, and Cerezo, Cockayne, Hutchison, Pettifor, Smith and Sykes have retired. The retirements gave us the opportunity to re-orient our research direction, making 11 appointments in the period of assessment aimed at strengthening research activity in previously identified strategic areas; theory and modelling (**Benjamin, Reed, Giustino**, **Yates**), energy materials (**Marrow, Moody, Lozano-Perez**, **Bruce**) manufacturing (**Galano, Bhaskaran**) and carbon nanomaterials (**Grobert, Warner**). These appointments evidence a balance of promoting internal rising stars (since 2009 **Giustino** has won both an ERC Starter Grant and a Leverhulme Research Leadership award), and bringing in new perspectives and capabilities. The appointments of **Bruce** to the Wolfson Chair, **Marrow,** and **Reed** to a joint chair with Engineering Science strengthen our leadership at the senior level.

Terms of appointment for academic staff, career development and equal opportunities: All academic staff engage in teaching and research. There are clear and transparent university

structures in place for re-grading of posts, to award additional pay on grounds of merit or temporary additional duties, and to retain exceptional staff. Since 2008, 6 members of academic staff have received substantial re-gradings. The HoD meets each member of the academic staff at least once a year (every 6 months for new appointments) to plan future research and teaching targets and to discuss any areas of concern. Typical outcomes may involve changes in teaching/research balance, connection with a mentor for specific research proposals, less/more involvement on research strategy, etc. These meetings also always address issues of work/life balance and the equal opportunities agenda. We strive to meet all requests for part-time working (e.g. to support a young family), and two members of academic staff are currently supported in part-time working.

Support for new academic staff members: All new academic staff have a senior mentor and progress is monitored at regular intervals throughout a five-year probationary period by a rigorous process overseen by the MPLS division. Teaching and administrative loads are kept as low as possible to facilitate building research activity, typically 12 hours/pa lecturing in the first 3 years. New academic staff are prioritised by the HoD for competitive applications to the university's internal research funding, a policy that has resulted in awards of ~£100k each to **Bhaskaran, Galano, Grobert, Lozano-Perez, Porfyrakis, Watt, Warner, Moody** and **Speller** to provide critical items of equipment. We also allocate new academic staff at least £25k on appointment, along with laboratory space and preferential access to institutional funding for research students.

Career development: We support the aspirations of academic staff to be promoted through the university's Recognition of Distinction exercise, with the HoD and senior members providing advice on applications, optimum timing, etc. In the past 5 years, the title of professor has been awarded to **Sykes** (2008), **Castell, Grobert, Nellist, Todd** and **Wilshaw** (2011) and **Wilkinson** (2012). Staff are encouraged to take advantage of the university sabbatical system (1 term for 7 worked), often to develop new directions in research, facilitated by other academic staff working collegially to provide cover for teaching. Administrative duties for all academic staff have been reduced by transferring many time-consuming responsibilities to a full-time Director of Studies post.

Visiting scholars: Since 2008, we have hosted 273 visitors from 22 countries, 40% from industry and 60% from HEIs. All academic visitors are attached to a research group and have well-defined research objectives. More than 20% of our research outputs have visitors as co-authors. We also have 4 formally appointed Visiting Professors: Drautz (Bochum), English (NNL), Falster (MEMC) and Dudarev (CCFE) who are required to contribute to the research environment by pro-actively mentoring younger staff, building research opportunities and co-authoring papers. For example, English has helped focus and coordinate research activities in nuclear materials and has assisted us in generating >£1M of new research funding in areas of strategic interest to the UK nuclear industry.

External Fellowship holders: We take pride in supporting the career development of younger researchers who will be the academic leaders of the future. In the past 5 years, 17 of our Fellowship holders (Barnard, Bishop, Marquis, Nicolosi, Kohn, Lovett, Kilburn, Marquis, Drautz, Ceresoli, Bonini, Kolmogorov, Margine, Morton, Murphy, Nicolosi and Lazarov) have left to take up permanent academic posts (including readerships or professorships) in the UK, Europe, USA, Australasia and Israel. We take care to provide a strong mentoring culture where academic staff identify promising graduate students and postdoctoral researchers, encourage them to apply for independent Fellowships (college and university posts and those supported by the EPSRC, Royal Society or Royal Academy of Engineering), advise on the application and offer mock interviews. Our candidates have a high success rate for such competitive Fellowships (>40% since 2008), and contribute strongly to our ethos of ambition and research scholarship. We currently host 3 RSURFs (**Grobert, Warner, Yates**), 4 RAE Research Fellows (**Galano, Speller, Laird, Armstrong**), 1 EPSRC Fellowship holder (**Moore**), 3 EPSRC Manufacturing or Nuclear Fellows (**Bhaskaran, Porfyrakis, Edmondson**) and a university Glasstone Fellow (**Simmons**). From the outset, these Early Career Researchers are mentored by senior staff to develop their own research groups at the forefront of materials science and to compete for external and internal research grants. For instance, **Grobert** now holds ERC Starter and POC grants. Fellowship holders have EPSRC DTA studentships guaranteed as part of the institutional support for their applications, and benefitted from >£200k of institutional EPSRC Small Equipment funding in 2012. Our Fellowship holders are

offered opportunities to develop their teaching skills, to participate in appropriate committees, to gain experience of examining, and to be the lead supervisors of PhD students.

Contract researchers: The Department hosts 64 postdoctoral researchers supported on external grants (44 in 2007). We support the career development of these fixed-term researchers by an active mentoring programme (improved by the Athena SWAN application process) involving an annual review of progress, encouragement and advice in applications for external fellowships, college research fellowships etc. Since 2008, 32 of these researchers have progressed to independent fellowships or full academic appointments in Oxford University or elsewhere. We encourage their involvement in the preparation and management of research projects (4 are EPSRC Named Researcher Co-Investigators, and 3 more take the lead on applications for synchrotron beamtime etc.), attending university and divisional personal and professional development training, to become members of professional bodies and serve on appropriate internal and external committees. More than 40% of postdoctoral researchers take advantage of opportunities to undertake some teaching, (Code of Practice: Principles 3 and 4), and more than 70 individual career development courses run by the Oxford Learning Institute have been attended by UOA researchers since 2008 (Code of Practice: Principles 2l, 2m, 2n, 2o); 80% of these attendees report that they provide excellent support for career development. Our researchers also play a full part in research, teaching and junior consultative committees (Code of Practice 4z). In recognition of our dedication to supporting and developing research staff, Oxford University has been awarded the EC's HR Excellence in Research Award which recognises the excellence of systems in place to support researchers' career and professional development.

ii. Research students

Our 139 graduate students in years 1-4 are drawn from over 30 countries, and 82% are fully-funded by studentships or scholarships. They underpin much of our research output and contribute critically to the feeling of energy and enthusiasm in our research environment, often achieving significant recognition in their own right e.g. 8 IoMMM awards since 2008 and >35 best student presentations in international conferences. We use £80k of discretionary funds each year to help research students attend conferences or summer schools or to support those towards the end of their projects who require (due to unforeseen circumstances) a short additional period of funding to write-up. All graduate students are provided with a laptop computer at the beginning of their studies configured with the software appropriate for their specific work requirements.

From ~120 well-qualified applicants each year, we recruit ~36 new research students, 50% and 42% higher respectively than in RAE2008. The ratio of PhD students to submitted staff is 4.1 (2.4 in 2008) because of our strategy to increase research capacity without compromising quality. This growth has been supported and overseen by the Graduate School of the MPLS division. The Director of Graduate Studies (DGS) and research supervisors provide support and advice both to applicants and to admitted students. Further support comes from the college to which each student also belongs, and peer support is provided by the Department's effective staff-student liaison committee, the JCCG. The quality of provision for research students is a key responsibility of the DGS and is regularly scrutinised by the JCCG, the MPLS Graduate School and the University Education Committee. New supervisors are required to have an experienced co-supervisor who, together with the HoD & DGS, provide supervision guidance and mentoring. Training courses on research supervision are provided by the Oxford Learning Institute.

Averaged over recent cohorts, 77% of students submit their theses within 4 years, and our aspiration is to reach 90% by 2018. DLHE surveys for the 2010-12 leavers indicated 94% in employment six months after graduation. In the recent Student Barometer surveys (2011 & 2012), 95% of our PhD student respondents indicated they were *satisfied* or *very satisfied* with their overall experience. The comprehensive annual feedback exercise run by our JCCG also demonstrates a very high overall level of satisfaction, and the detailed feedback it provokes provides a key tool to help us improve our provision.

PGR recruitment: We attract research students from diverse backgrounds from the UK and around the world using an accessible web-based graduate application system, and both the university's Graduate Admissions & Funding Office and our staff provide detailed information and advice to prospective students via the web and via overseas visits (e.g. to China and India). Places are offered through gathered fields to ensure equitable and transparent selection. All short-listed

candidates are interviewed, by Skype if necessary. We ascribe our continued growth in applicant numbers to the particular efforts we have made to: (i) provide research topics at the forefront of the subject, with clear industrial and societal relevance and supervised by leading scientists; (ii) substantial growth in competitive student funding secured by our staff from the EU, industry and personal donors; and (iii) efficient and direct personal interaction with all applicants. We are looking forward to participating in 3 new CTDs in 2014: Theory and Modelling in Chemical Sciences (led by Oxford, **Giustino** and **Yates**), Diamond Science (Warwick-led, **Smith** and **Todd**) and Photovoltaics (Liverpool-led, **Assender**, **Giustino**, **Watt**), with 1 other centre in Fusion still under consideration.

Training: Graduate induction takes place over two days to introduce key people, facilities and procedures. Compulsory elements of training for the Year 1 cohort include safety, project management led by a senior scientist from industry, satisfactory performance on two taught and assessed academic courses, a forward look at career planning and the desires of prospective employers led by alumni of the UOA, and attendance at research colloquia by leading scientists from industry and academia worldwide. With the guidance of supervisors, students choose training from over 350 transferable and subject-specific lecture courses, skills workshops and hands-on experimental technique training modules available at departmental, divisional, university & national level. For example the Said Business School offers a popular course 'Building a Business' attended by >10 of our students each year. We provide a range of opportunities to gain teaching experience at undergraduate (primarily through lab demonstrating) and school level, the latter through our substantial Schools Outreach Programme. These opportunities are outlined in our Graduate Course Handbook, and 70% of graduate students engage in some teaching.

Progress monitoring, progression and submission: We operate a compulsory doctoral research project management (PM) scheme requiring each student to assess and report in writing on progress at 6-monthly intervals in order to train them to take responsibility for their progress. This has been a key tool in meeting 4-year submission rate targets. These PM reports are considered by supervisors and the DGS. In addition, three formal reports per year are required from supervisors and these are discussed with the student, who may submit their own self-report (40% choose to supplement their compulsory project management reports in this way). The GSS reports are considered by the university's Graduate Studies Office, the student's college and the DGS. There are two formal milestones in a research student's progression: (i) in Year 2 whether sufficient ability and application has been demonstrated to warrant transfer to the doctoral cohort and (ii) in Year 3 whether the student is on-track for timely submission of a doctoral thesis. Written work and oral presentations are a requirement of both milestones and are formally assessed. Where concerns are raised at the transfer or confirmation milestones, the student is provided with targeted support agreed following consultation between the student, supervisors and DGS, typically for a 3-month period after which they are re-assessed. On average 2 students per year fail to attain PhD status, some transferring to our 2-year MSc(Research) programme. Overall, 91% of our research students submit a successful thesis.

d. Income, Infrastructure and Facilities

Income

Our research income comes from a wide range of sources, and provides for an annual research expenditure averaging £6.5M (~£190k per submitted FTE each year). Over the period of assessment, 57% of income came from RCUK, 16% from European funding and ~10% directly from industry, including a number of major donations, for instance £1M from JEOL to support electron microscopy activities. A significant fraction of the industrial contribution is in the form of sponsorship of doctoral students, either fully funded (12 projects in total) or through CASE awards (10 current projects and 7 more completed since 2008), more than double the number in RAE2008. Some significant activities in the period of assessment include:

- Greater use of Diamond Light Source, ISIS neutron source, national supercomputing facilities and SuperSTEM, with allocations increased from £128k (08/09) to £845k (11/12), providing new insights on the failure of nuclear quasi-brittle materials, dendrite growth processes, trace element localisation in rice grain and in-situ studies of metal-forming processes.
- Granted patent and licensing agreement activity has increased by 70% since 2008.
- EU FP7 and European Research Council research income increased by a factor of 5 since 2007 to an average > €2M p.a. (much of it associated with early career researchers).

- Although we have grown RCUK income overall, the fraction of our total income represented by RCUK awards has reduced from >70% in 07/08 to 54% in 12/13, evidencing our strategy to diversify external grant revenues.

As evidence of the extent of our activity in forming new alliances, academic staff have been involved since January 2008 in setting up with industrial partners:

- 18 new collaboration agreements
- > 80 new confidentiality agreements
- 8 new research sponsorship deals (to a total value of £2.2M)
- 29 fully or partially funded studentships (with a total value of £1.2M)

Buildings and infrastructure

The department occupies a total of ~7,600 m^2 distributed across 6 adjacent buildings in the central Science Area, and 3 co-located buildings at the Begbroke Science Park, which is an innovation and science park owned by the university 5 miles north of Oxford. The Begbroke site (an initiative originally conceived by the UOA) has become the focus of our industrial and larger scale research, especially in manufacturing, as well as providing a stable environment for some of our more sensitive electron microscopes. The Begbroke site (which also contains research activities from Engineering Science, Earth Sciences, Chemistry, the Oxford supercomputer, etc, as well as many small high-tech science companies) is served by 3 free minibuses operating a near-continuous shuttle to ensure convenient connections to the Science Area and the colleges, along with recently upgraded high bandwidth fibre optics. At Begbroke we are fitting out 200 m^2 of new laboratories for **Reed** (£400k) and taken new office space for the growing **Grobert** Group. On the main Science Area, we occupy 300 m^2 of additional space for the expanded Materials Modelling Laboratory and 350 m^2 is currently being refitted for **Bruce's** laboratories at a cost of >£3M.

Facilities

We operate much of our experimental apparatus as Small Research Facilities, so providing a transparent mechanism to recover equipment costs and depreciation through access charges that ensure sustainability of our research activity. Amongst a broad portfolio of experimental facilities:

- We have the only Atom Probe Tomography facility in the UK, that supports directly the research of 5 academic staff, as well as facilitating collaborations with Caltech, Cadiz and Cambridge and industrial partners from JFE Steels, Rolls-Royce, Hitachi, Kobe Steel, POSCO, Tata, Westinghouse, EdF, Mannesmann and Areva.
- We have built up a substantial suite of major facilities for liquid metal processing including direct chill casting (up to 300 kg), spray forming (up to 60 kg) and plasma spraying (production scale) used, for example, to secure new research partnerships with MHI (Japan), Baosteel and Beijing Institute for Aerospace Materials (China) and SAPA (Sweden).
- A production-scale web coater has been a key facility in joint TSB and EPSRC funded research activities with 11 companies, and is the only research facility of its kind in the UK.
- More than 70% of the time on our CAMECA NanoSIMS (one of only 2 in the UK) has been committed to project work with external partners including Westinghouse, NPL, UCLA, Rothamsted Research and local hospitals.
- We have provided access for more than 80 independent academic groups to our EM facilities under national and EU projects (EPSRC: OXTEM, EU FP6: ESTEEM and FP7: ESTEEM2, £1.9M in total), resulting in > 50 joint publications.
- We have invested heavily in new facilities during the period of assessment, especially prioritising the area of characterisation for a refresh of key instruments. A Zeiss NVision dual beam FIB (£1M) in 2009 has proved vital in the expansion of work on micromechanical testing, site-specific TEM and APT sample preparation, 3D sectioning etc, supporting the research of >40 researchers funded by >10 industrial or RCUK projects.
- A joint project between Physics and Materials generated internal funding for a JEOL 5500FS electron beam lithography tool for general use (£880k). This has been vital for new projects in graphene and quantum devices.
- Major equipment purchased on external grants includes a further Zeiss Auriga FIB, a unique high temperature nanoindenter and a shared electron spin resonance facility in Chemistry.
- We led a successful £2.1M EPSRC Capital Equipment bid (with Bristol and Southampton) for a state-of-the-art analytical TEM to be installed in 2014, and also committed £630k of institutional

funds in 2013 to refresh SEM and additional TEM facilities.
- A further ~£4.6M from successful applications to the EPSRC 8 Great Technologies capital round scheme in 2013 is now being invested in new manufacturing and characterisation facilities for alloys for extreme environments (vacuum plasma spraying, spark plasma sintering, vacuum casting, Gleeble, calorimetry, etc) and energy storage (3D nano-printing, high throughput XPS, graded electrode fabrication, *in-situ* TEM of batteries, etc).
- The National Nuclear User Facility project announced by the Government Chief Scientist in 2013 has contributed £1.6M towards new active handling and experimental facilities for nuclear materials research led by the UOA on the nearby Culham campus, with a further £3.3M committed in 2014/15.

Future plans
- Our vision is to consolidate all our Science Area research activity into a single integrated building focused on basic science and where close collaboration with cognate departments in the Science Area is paramount, while retaining the high quality and large scale laboratories for manufacturing, scale-up and specific high-end instruments at Begbroke.
- The appointment of Peter Bruce will be used to integrate the university's wider energy materials research into a new *Oxford Energy Institute*, which we aim to site within our new building in the Science Area. New academic appointments in Materials, Chemistry and Engineering associated with OEI are already planned, together with bids for both internal and external support, focused on an ambitious interdisciplinary research programme in energy.
- We will continue to rebalance our research portfolio towards overseas industrial funding, with new opportunities already emerging in Korea and China. For example, we are discussing new modes of collaborative research and funding in partnership with overseas science parks that map closely to our strategic research goals in energy, quantum devices and nanomaterials.
- Future equipment capital plans will focus on quantum and nano-device manufacture and characterisation, a programme which has already started with £850k to install dilution fridges.
- We will continue to develop our emphasis on growing our portfolio of "longer-larger" high impact RCUK grants in our strategic areas, seeking to lead about 25% of these.
- We will deepen our strategic relationships with CCFE (including joint appointments in support of the National Nuclear User Facility) and with the Harwell Campus (Centre for Electron Microscopy) that will generate new funding opportunities.

e. Collaboration or contribution to the discipline or research base

We have taken the lead in developing many vibrant interactions with industry, researchers in other HEIs, learned societies and UK and EU funding councils. For example, the Bristol/Oxford Nuclear Research Centre was launched in 2011 and involves 6 of our staff. The centre works across a broad spectrum of nuclear research from fundamental science to the socio-economic impact of new nuclear build in the UK. Strong research relationships also exist with many HEIs through EPSRC Programme Grants, IeMRC Flagship projects, a Centre for Innovative Manufacturing in Liquid Metal Engineering, EPSRC SuperGen and EPSRC Grand Challenges, etc. Our staff play leading roles in national and international partnerships, for example, **Nellist** is Scientific Champion of the EPSRC National Facility for Aberration Corrected STEM (SuperSTEM), **Kirkland** is Scientific Coordinator for ESTEEM2, **Giustino** is a member of the J.C. Maxwell Node of CECAM.

Substantive research collaborations – defined as involving both mutual visits and joint research publications - exist with >45 institutions in the UK, 25 in Europe, 17 in the USA, 3 in India, 3 in Japan, 12 in China, 3 in Australia, and in Korea, Argentina, Taiwan, Singapore and South Africa. Academic staff from these institutions appeared as co-authors on > 50% of our research outputs, and examples of specific developments arising from these relationships include: research on electron microscope components with JEOL that led to >10 publications as well as new products in the marketplace; new programmes on active nuclear materials with UCSB, Areva and INSS that now support >20 individual projects producing 25 papers in 2013; research arising from a Royal Society Newton Fellow from Tsinghua University that led to the most sophisticated current model of dendrite behaviour during solidification; and collaboration with colleagues in Singapore and Brisbane that has defined a methodology to achieve fault-tolerant quantum computing.

To encourage our staff to develop interdisciplinary collaborations, reductions in administrative duties and buy-out of teaching are offered, especially to facilitate the building of new strategic

partnerships. For instance, our emergence as a centre of excellence for micromechanical testing of nuclear materials under the guidance of **Roberts** led to new projects on Radiation Damage In Accelerator Target Environments with Fermilab and STFC. Alternatively, by making appointments in targeted areas of high international research activity, such as C-nanomaterials, we have also been able to develop new, productive international collaborations including bio-materials for orthopaedics (**Grobert** with Cambridge and Marburg), carbon nanotubes for drug delivery (**Grobert** with Toyo University and UPMC, France) and graphene scaffolds for stem cell differentiation (**Warner** with Pretoria University).

Examples of **External Honours** for our staff have included: 2012 Verulam Medal and Prize of the IOMMM (**Todd**), 2013 Ernst Ruska Prize from the German Society for Electron Microscopy (**Nellist**), 2008 Massey Medal of IOP (**Cockayne**) and a 2012 Leverhulme Research Leadership Award (**Giustino**). **Grant** was elected a Fellow of the IOM3 in 2009 and Fellow of the Royal Academy of Engineering in 2010. Royal Society URFs were awarded to **Warner** 2010 **and** RAEng Fellowships to **Laird** and **Armstrong** 2013. **Warner** (2011) and **Grobert** (2013) were elected as World Economic Forum Champions at the *Summer Davos* in Dalian.

Consultancies, Directorships and Professional Services: We aim for our staff to make use of the university's generous allowance of up to 30 days for external activities. We believe that acting as a consultant, especially for industry, is an excellent way for our staff to be exposed to new directions in the discipline, and engenders a wider external perspective that then helps improve our internal decision-making. Since 2008, 14 members of staff have held *substantive* consultancies or directorships with 38 different external organisations, including Rolls-Royce, EdF, De La Rue Ltd, TWI, Crown Cork and Seal, the Office of the Nuclear Regulator, Constellium, Thoratec Corp., MFN Ltd. and Accelerys.

Engagement in Learned Societies: Nellist: Council (2010) and then Fellow and Vice President of Royal Microscopical Society (2012), Chair of Electron Microscopy and Analysis Group of Institute of Physics (2010), **Assender**: IOP Polymer Physics Group Committee, **Grobert:** Royal Society Hooke Committee and Rosalind Franklin Committee Member, **Castell, Czernuszka, Galano, Grant, O'Reilly, Todd**: Committees of IOM3, **Brigg**s: Science Scholarships Committee of Royal Commission for the Exhibition of 1851.

Editorships of journals: Todd: Editor, Journal of the European Ceramic Society since 2007**, Kirkland:** Editor in Chief, Ultramicrosopy since 2010, **Giustino**: Associate Editor, European Physical Journal B since 2012**.** Other members of staff serve on the editorial boards of 19 international journals, and have acted as editors for > 20 conference proceedings.

Research Councils: Most members of academic staff serve on the EPSRC College, and 8 have acted as chairs of EPSRC Panels. **Grant** serves on the EPSRC Strategic Advisor Network (2011-) and the EPSRC Manufacturing the Future Advisory Team (2010-), **Grobert**, **Kirkland** and **Grovenor** act as strategic advisors *inter alia* for research councils in Germany, Norway, Greece, Russia, South Africa, Denmark and Austria.

Advisory Committees: Roberts: European Strategy Forum on Research Infrastructure**, Grant:** EPSRC/STFC Fusion Advisory Board (2007-2012), Rolls-Royce Materials, Manufacturing and Structures Advisory Board (2009-), HEFCE Research Assessment Exercise Panel 2008 for Metallurgy and Materials, Foresight Future of Manufacturing (2013) Evidence Paper 10: *New and Advanced Materials***, Assender:** IoP IPSI group and APT & CMMP division committees (2008-10)**, Grobert**: Member British Carbon Group Committee, ERC Founding/Board Member of the Young Academy of Europe, **Galano:** Advisory Committee of the Int. Scientific and Technology Cooperation Program Argentina**, Wilkinson:** Vice Chair Board for ICSMA, Scientific Committee for the CNRS MECANO (2012-2016)**, Kirkland:** Advisor to the Department of Science, South Africa, National Centre for Electron Microscopy (NMMU, SA), Chair, User Working Group for I14, Diamond Light Source.

International appointments: Many members of the Department hold substantive appointments abroad, including visiting Professorships at University of NSW and Wuhan University (**Briggs**), National Tsinghua U. Taiwan and NMMU (**Kirkland**), Toyo University, Japan (**Grobert**)